SECTION 13 - WOOD STRUCTURES

13.1 GENERAL AND NOTATIONS

13.1.1 General

The following information on wood design is generally based on the National Design Specification for Wood Construction (NDS®), 1991 Edition. See the 1991 Edition of the NDS® for additional information.

13.1.2 Net Section

In determining the capacity of wood members, the net section of the member shall be used. Unless otherwise noted, the net section shall be determined by deducting from the gross section, the projected area of all material removed by boring, grooving, dapping, notching or other means.

F_b^*

13.1.3 Impact

In calculating live load stresses in wood, impact shall be neglected unless otherwise noted. See Article 3.8.1.

13.1.4 Notations

a = coefficient based on support conditions for tapered columns (Article 13.7.3.4.2)
b = width of bending member (Article 13.6.4.3)
c = coefficient based on sawn lumber, round timber piles, glued laminated timber or structural composite lumber (Article 13.7.3.3.5)
C_D = load duration factor (Article 13.5.5.2)
C_F = bending size factor for sawn lumber, structural composite lumber, and for glued laminated timber with loads applied parallel to the wide face of the laminations (Article 13.6.4.2)
C_F = compression size factor for sawn lumber (footnotes to Table 13.5.1A)
C_F = tension size factor for sawn lumber (footnotes to Table 13.5.1A) and structural composite lumber (footnotes to Tables 13.5.4A and 13.5.4B)
C_H = shear stress factor (footnotes to Table 13.5.1A)
C_L = beam stability factor (Article 13.6.4.4)
C_M = wet service factor (Article 13.5.5.1)
C_P = column stability factor (Article 13.7.3.3)
C_V = volume factor for glued laminated timber with loads applied perpendicular to the wide face of the laminations (Article 13.6.4.3)
C_b = bearing area factor (Article 13.6.6.3)
C_f = from factor (Article 13.6.4.5)
C_{fu} = flat use factor for sawn lumber (footnotes to Table 13.5.1A)
C_r = repetitive member factor for sawn lumber (footnotes to Table 13.5.1A)
d = depth of member (Article 13.6.4.2.2)
d_{max} = maximum column face dimension (Article 13.7.3.4.2)
d_{min} = minimum column face dimension (Article 13.7.3.4.2)
d_{rep} = representative dimension for a tapered column face (Article 13.7.3.4.2)
E = tabulated modulus of elasticity (Article 13.6.3)
E' = allowable modulus of elasticity (Article 13.6.3)
F_b = tabulated unit stress in bending (Article 13.6.4.1)
F'_b = allowable unit stress in bending (Article 13.6.4.1)
= adjusted tabulated bending stress for beam stability (Article 13.6.4.4.5)
F_c = tabulated unit stress in compression parallel to grain (Article 13.7.3.2)
F'_c = allowable unit stress in compression parallel to grain (Article 13.7.3.2)
= adjusted tabulated stress in compression parallel to grain for column stability (Article 13.7.3.3.5)
f_c = actual unit stress in compression parallel to

grain (Article 13.7.3.1)

$F_{c\perp}$ = tabulated unit stress in compression perpendicular to grain (Article 13.6.6.2)

F'_c = allowable unit stress in compression perpendicular to grain (Article 13.6.6.2)

F_g = tabulated unit stress in bearing parallel to grain (Article 13.7.4.1)

= allowable unit stress in bearing parallel to grain (Article 13.7.4.1)

F_t = tabulated unit stress in tension parallel to grain (Article 13.8.1)

= allowable unit stress in tension parallel to grain (Article 13.8.1)

F_v = tabulated unit stress in shear parallel to grain (Article 13.6.5.3)

= allowable unit stress in shear parallel to grain (Article 13.6.5.3)

f_v = actual unit stress in shear parallel to grain (Article 13.6.5.2)

= allowable unit stress for bearing on an inclined surface (Article 13.6.7)

K = column effective length factor (Article 13.7.3.3.3)

K_{bE} = material factor for beam stability (Article 13.6.4.4.5)

K_{cE} = material factor for column stability (Article 13.7.3.3.5)

L = length of bending member between points of zero moment (Article 13.6.4.3.1)

l = actual column length between points of lateral support (Article 13.7.3.3.3)

l_b = length of bearing (Article 13.6.6.3)

l_e = effective bending member length (Article 13.6.4.4.3)

l_e = effective column length (Article 13.7.3.3.3)

l_u = unsupported bending member length (Article 13.6.4.4.3)

m = parameter for the specific material determined in accordance with the requirements of ASTM D-5456 (Tables 13.5.4A and 13.5.4B)

R_B = bending member slenderness ratio (Article 13.6.4.4.4)

V = vertical shear (Article 13.6.5.2)

V_{LD} = maximum vertical shear at 3d or L/4 due to wheel loads distributed laterally as specified for moment (Article 13.6.5.2)

V_{LL} = distributed live load vertical shear (Article 13.6.5.2)

V_{LU} = maximum vertical shear at 3d or L/4 due to undistributed wheel loads (Article 13.6.5.2)

x = species variable for computing the volume factor (Article 13.6.4.3.1)

θ = angle between the direction of load and the direction of grain (Article 13.6.7)

13.2 MATERIALS

13.2.1 Sawn Lumber

13.2.1.1 General

Sawn lumber shall comply with the requirements of AASHTO M 168.

13.2.1.2 Dimensions

13.2.1.2.1 Structural calculations for sawn lumber shall be based on the net dimensions of the member for the anticipated use conditions. These net dimensions depend on the type of surfacing, whether dressed, rough-sawn or full-sawn.

13.2.1.2.2 For dressed lumber, the net dry dimensions given in Table 13.2.1A shall be used for design, regardless of the moisture content at the time of manufacture or in use.

13.2.1.2.3 Where the design is based on rough, full-sawn or special sizes, the applicable moisture content and dimensions used in design shall be noted in the plans and specifications.

TABLE 13.2.1A Net Dry Dimensions for Dressed Lumber

	Nominal Thickness	Dry Thickness	Nominal Width	Dry Width
Dimension Lumber (inches):	2 2-1/2 3 3-1/2 4 4-1/2	1-1/2 2 2-1/2 3 3-1/2 4	2 3 4 5 6 8 10 12 14 16	1-1/2 2-1/2 3-1/2 4-1/2 5-1/2 7-1/4 9-1/4 11-1/4 13-1/4 15-1/4
Beams and Stringers	5" and greater	1/2" less than nominal	5" and greater	1/2" less than nominal
Posts and Timbers	5" and greater	1/2" less than nominal	5" and greater	1/2" less than nominal

13.2.2 Glued Laminated Timber

13.2.2.1 General

Glued laminated timber shall comply with the requirements of AASHTO M 168 and shall be manufactured using wet-use adhesives.

13.2.2.2 Dimensions

13.2.2.2.1 Structural calculations for glued laminated timber shall be based on the net finished dimensions.

13.2.2.2.2 For Western Species and Southern Pine, the standard net finished widths shall be as given in Table 13.2.2A. Other, nonstandard finished widths may be used subject to design requirements.

TABLE 13.2.2A Standard Net Finished Widths of Glued Laminated Timber Manufactured from Western Species or Southern Pine

Western Species Net Finished Width (in.)	Southern Pine Net Finished Width (in.)
3-1/8	3
5-1/8	5
6-3/4	6-3/4
8-3/4	8-1/2
10-3/4	10-1/2
12-1/4	12
14-1/4	14

13.2.3 Structural Composite Lumber

13.2.3.1 General

Structural composite lumber, including laminated veneer lumber and parallel strand lumber, shall comply with the requirements of ASTM D 5456 and shall be manufactured using wet-use adhesives which comply with requirements of ASTM D 2559.

13.2.3.2 Laminated Veneer Lumber

Laminated veneer lumber shall consist of a composite of wood veneer sheet elements with wood fibers oriented primarily along the length of the member. Veneer thickness shall not exceed 0.25 inches.

13.2.3.3 Parallel Strand Lumber

Parallel strand lumber shall consist of wood strand elements with wood fibers oriented primarily along the length of the member. The least dimension at the strands shall not exceed 0.25 inches and the average length shall be a minimum of 150 times the least dimension.

13.2.3.4 Dimensions

Structural calculations for structural composite lumber shall be based on the net finished dimensions.

13.2.4 Piles

Wood piles shall comply with the requirements of AASHTO M 168.

13.3 PRESERVATIVE TREATMENT

13.3.1 Requirement for Treatment

All wood used for structural purposes in exposed permanent applications shall be pressure impregnated with wood preservative in accordance with the requirements of AASHTO M 133.

13.3.2 Treatment Chemicals

All structural members that are not subject to direct pedestrian contact shall preferably be treated with oil-type preservatives. Members that are subject to direct pedestrian contact, such as rails and footpaths, shall be treated with waterborne preservatives or oilborne preservatives in light petroleum solvent. Direct pedestrian contact is considered to be contact which may be made while the pedestrian is situated anywhere in the access route provided for pedestrian traffic.

13.3.3 Field Treating

Insofar as is practicable, all wood members shall be designed to be cut, drilled, and otherwise fabricated prior to pressure treatment with wood preservatives. When cutting, boring, or other fabrication is necessary after preservative treatment, exposed, untreated wood shall be specified to be field treated in accordance with the requirements of AASHTO M 133.

13.3.4 Fire Retardant Treatments

Fire-retardant chemicals shall not be used unless it is demonstrated that they are compatible with the preservative treatment. When fire retardants are used, design values shall be reduced by the strength and stiffness reduction factors specified by the fire retardant chemical manufacturer.

13.4 DEFLECTION

13.4.1 The term "deflection" as used herein shall be the deflection computed in accordance with the assumptions made for loading when computing stress in the members.

13.4.2 Flexural members of bridge structures shall be designed to have adequate stiffness to limit deflections or any deformations that may adversely affect the strength or serviceability of the structure.

13.4.3 Members having simple or continuous spans preferably should be designed so that the deflection due to service live load does not exceed $^{1}/_{500}$ of the span.

13.4.4 For timber deck structures with timber girders or stringers of equal stiffness, and cross-bracing or diaphragms sufficient in depth and strength to ensure lateral distribution of loads, the deflection may be computed by considering all girders or stringers as acting together and having equal deflection. When the cross-bracing or diaphragms are not sufficient to laterally distribute loads, deflection shall be distributed as specified for moment.

13.4.5 For concrete decks on wood girders or stringers, the deflection shall be assumed to be resisted by all beams or stringers equally.

13.5 DESIGN VALUES

13.5.1 General

Stress and modulus of elasticity values used for design, referred to as allowable design values, shall be the tabulated values modified by all applicable adjustments required by this Section. The actual stress due to loading shall not exceed the allowable stress.

13.5.2 Tabulated Values for Sawn Lumber

13.5.2.1 Tabulated values for sawn lumber are given in Table 13.5.1A for visually graded lumber and Table 13.5.1B for mechanically graded lumber. Values for bearing parallel to grain are given in Table 13.5.2A. These values are taken from the 1991 Edition of the NDS® and represent a partial listing of available species and grades. Refer to the 1991 Edition of the NDS® for a more complete listing.

13.5.2.2 Stress Grades in Flexure

13.5.2.2.1 The tabulated unit bending stress for Dimension (2 to 4 inches thick) and Post and Timber grades applies to material with the load applied either to the narrow or wide face.

13.5.2.2.2 The tabulated unit bending stress for Decking grades applies only when the load is applied to the wide face.

13.5.2.2.3 The tabulated unit bending stress for Beam and Stringer grades applies only when the load is applied to the narrow face. When Post and Timber sizes are graded to Beam and Stringer grade requirements, the tabulated unit bending stress for the applicable Beam and Stringer grades may be used.

13.5.2.2.4 Beam and Stringer grades are normally graded for use as a single, simple span. When used as a continuous beam, the grading provisions customarily applied to the middle third of the simple span length shall be applied to the middle two-thirds of the length for two-span beams, and to the entire length for beams continuous over three or more spans.

13.5.3 Tabulated Values for Glued Laminated Timber

13.5.3.1 Tabulated values for glued laminated timber of softwood species are given in Tables 13.5.3A and 13.5.3B. Values for bearing parallel to grain are given in Table 13.5.2A. These values are taken from the 1993

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers

Species and Commercial Grade	Size Classification	Bending F_b	Tension Parallel to Grain F_t	Shear Parallel to Grain F_v	Compression Perpendicular to Grain $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	Grading Rules Agency
		Design Values in Pounds per Square Inch (psi)						
DOUGLAS FIR-LARCH								
Select Structural		1450	1000	95	625	1700	1,900,000	
No. 1 & Btr	2"-4" thick	1150	775	95	625	1500	1,800,000	WWPA
No. 1		1000	675	95	625	1450	1,700,000	
No. 2	2" & wider	875	575	95	625	1300	1,600,000	WCLIB
Dense Select Structural		1900	1100	85	730	1300	1,700,000	
Select Structural	Beams and	1600	950	85	625	1100	1,600,000	
Dense No. 1	Stringers	1550	775	85	730	1100	1,700,000	
No. 1		1350	675	85	625	925	1,600,000	
No. 2		875	425	85	625	600	1,300,000	WCLIB
Dense Select Structural		1750	1150	85	730	1350	1,700,000	
Select Structural	Posts and	1500	1000	85	625	1150	1,600,000	
Dense No. 1	Timbers	1400	950	85	730	1200	1,700,000	
No. 1		1200	825	85	625	1000	1,600,000	
No. 2		750	475	85	625	700	1,300,000	
Dense Select Structural		1850	1100	85	730	1300	1,700,000	
Select Structural		1600	950	85	625	1100	1,600,000	
Dense No. 1	Beams and	1550	775	85	730	1100	1,700,000	
No. 1	Stringers	1350	675	85	625	925	1,600,000	
Dense No. 2		1000	500	85	730	700	1,400,000	
No. 2		875	425	85	625	600	1,300,000	WWPA
Dense Select Structural		1750	1150	85	730	1350	1,700,000	
Select Structural		1500	1000	85	625	1150	1,600,000	
Dense No. 1	Posts and	1400	950	85	730	1200	1,700,000	
No. 1	Timbers	1200	825	85	625	1000	1,600,000	
Dense No. 2		800	550	85	730	550	1,400,000	
No. 2		700	475	85	625	475	1,300,000	
EASTERN SOFTWOODS								
Select Structural		1250	575	70	335	1200	1,200,000	
No. 1	2"-4" thick	775	350	70	335	1000	1,100,000	NELMA
No. 2	2" & wider	575	275	70	335	825	1,100,000	NSLB

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers (Continued)

Species and Commercial Grade	Size Classification	Bending F_b	Tension Parallel to Grain F_t	Shear Parallel to Grain F_v	Compression Perpendicular to Grain $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	Grading Rules Agency
		Design Values in Pounds per Square Inch (psi)						
HEM-FIR								
Select Structural		1400	900	75	405	1500	1,600,000	
No. 1 & Btr	2"-4" thick	1060	700	75	405	1350	1,500,000	WWPA
No. 1		950	600	75	405	1300	1,500,000	
No. 2	2" & wider	850	500	75	405	1250	1,300,000	WCLIB
Select Structural	Beams and	1300	750	70	405	925	1,300,000	WCLIB
No. 1	Stringers	1050	525	70	405	750	1,300,000	
No. 2		675	350	70	405	500	1,100,000	
Select Structural	Posts and	1200	800	70	405	975	1,300,000	
No. 1	Timbers	975	650	70	405	850	1,300,000	
No. 2		575	375	70	405	575	1,100,000	
Select Structural	Beams and	1250	725	70	405	925	1,300,000	WWPA
No. 1	Stringers	1050	525	70	405	775	1,300,000	
No. 2		675	325	70	405	475	1,100,000	
Select Structural	Posts and	1200	800	70	405	975	1,300,000	
No. 1	Timbers	950	650	70	405	850	1,300,000	
No. 2		525	350	70	405	375	1,100,000	
MIXED SOUTHERN PINE								
Select Structural		2050	1200	100	565	1800	1,600,000	SPIB
No. 1	2"-4" thick	1450	875	100	565	1650	1,500,000	
No. 2	2"-4" wide	1300	775	90	565	1650	1,400,000	
Select Structural		1850	1100	90	565	1700	1,600,000	
No. 1	2"-4" thick	1300	750	90	565	1550	1,500,000	
No. 2	5"-6" wide	1150	675	90	565	1550	1,400,000	
Select Structural	2"-4" thick	1750	1000	90	565	1600	1,600,000	
No. 1		1200	700	90	565	1450	1,500,000	
No. 2	8" wide	1050	625	90	565	1450	1,400,000	
Select Structural	2"-4" thick	1500	875	90	565	1600	1,600,000	
No. 1		1050	600	90	565	1450	1,500,000	
No. 2	10" wide	925	550	90	565	1450	1,400,000	

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers

Species and Commercial Grade	Size Classification	Bending F_b	Tension Parallel to Grain F_t	Shear Parallel to Grain F_v	Compression Perpendicular to Grain $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	Grading Rules Agency
		Design Values in Pounds per Square Inch (psi)						
Select Structural	2"-4" thick	1400	825	90	565	1550	1,600,000	
No. 1		975	575	90	565	1400	1,500,000	
No. 2	12" wide	875	525	90	565	1400	1,400,000	
MIXED SOUTHERN PINE (Dry or Wet Service Conditions)								
Select Structural	5"× 5"	1500	1000	110	375	900	1,300,000	
No. 1	& larger	1350	900	110	375	800	1,300,000	SPIB
No. 2		850	550	95	375	525	1,000,000	
NORTHERN RED OAK								
Select Structural		1400	800	110	885	1150	1,400,000	
No. 1	2"-4" thick	1000	575	110	885	925	1,400,000	
No. 2	2" & wider	975	575	110	885	725	1,300,000	
Select Structural	Beams and	1600	1950	105	885	950	1,300,000	
No. 1	Stringers	1350	675	105	885	800	1,300,000	
No. 2		875	425	105	885	500	1,000,000	NELMA
Select Structural	Posts and	1500	1000	105	885	1000	1,300,000	
No. 1	Timbers	1200	800	105	885	875	1,300,000	
No. 2		700	475	105	885	400	1,000,000	
RED MAPLE								
Select Structural		1300	750	105	615	1100	1,700,000	
No. 1	2"-4" thick	925	550	105	615	900	1,600,000	
No. 2	2" & wider	900	525	105	615	700	1,500,000	
Select Structural	Beams and	1500	875	100	615	900	1,500,000	
No. 1	Stringers	1250	625	100	615	750	1,500,000	
No. 2		800	400	100	615	475	1,200,000	NELMA
Select Structural	Posts and	1400	925	100	615	950	1,500,000	
No. 1	Timbers	1150	750	100	615	825	1,500,000	
No. 2		650	425	100	615	375	1,200,000	

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers (Continued)

Species and Commercial Grade	Size Classification	Design Values in Pounds per Square Inch (psi)						Grading Rules Agency
		Bending F_b	Tension Parallel to Grain F_t	Shear Parallel to Grain F_v	Compression Perpendicular to Grain $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	
RED OAK								
Select Structural		1150	675	85	820	1000	1,400,000	
No. 1	2"-4" thick	825	500	85	820	825	1,300,000	
No. 2	2" & wider	800	475	85	820	625	1,200,000	
Select Structural	Beams and	1350	800	80	820	825	1,200,000	
No. 1	Stringers	1150	550	80	820	700	1,200,000	
No. 2		725	375	80	820	450	1,000,000	NELMA
Select Structural	Posts and	1250	850	80	820	875	1,200,000	
No. 1	Timbers	1000	675	80	820	775	1,200,000	
No. 2		575	400	80	820	350	1,000,000	
SOUTHERN PINE								
Select Structural		2850	1600	100	565	2100	1,300,000	SPIB
No. 1	2"-4" thick	1850	1050	100	565	1850	1,300,000	
No. 2	2"-4" wide	1500	825	90	565	1650	1,100,000	
Select Structural		2550	1400	90	565	2000	1,800,000	
No. 1	2"-4" thick	1650	900	90	565	1750	1,700,000	
No. 2	5"-6" wide	1250	725	90	565	1600	1,600,000	
Select Structural		2300	1300	90	565	1900	1,800,000	
No. 1	2"-4" thick	1500	825	90	565	1650	1,700,000	
No. 2	8" wide	1200	650	90	565	1550	1,600,000	
Select Structural	2"-4" thick	2050	1100	90	565	1850	1,800,000	
No. 1	10" wide	1300	725	90	565	1600	1,700,000	
No. 2		1050	575	90	565	1500	1,600,000	
Select Structural		1900	1050	90	565	1800	1,800,000	
No. 1	2"-4" thick	1250	675	90	565	1600	1,700,000	
No. 2	12" wide	975	550	90	565	1450	1,600,000	

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers (Continued)

Species and Commercial Grade	Size Classification	Design Values in Pounds per Square Inch (psi): Bending F_b	Tension Parallel to Grain F_t	Shear Parallel to Grain F_v	Compression Perpendicular to Grain $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	Grading Rules Agency
SOUTHERN PINE (Dry or Wet Service Conditions)								
Dense Select Structural		1750	1200	110	440	1100	1,600,000	
Select Structural	5"x5"	1500	1000	110	375	950	1,500,000	
No. 1	& larger	1350	900	110	375	825	1,500,000	SPIB
No. 2		850	550	100	375	525	1,200,000	
SPRUCE-PINE-FIR								
Select Structural	2"-4" thick	1250	675	70	425	1400	1,500,000	
No. 1/No. 2	2" & wider	875	425	70	425	1100	1,400,000	
Select Structural	Beams and	1100	650	65	425	775	1,300,000	
No. 1	Stringers	900	450	65	425	625	1,300,000	
No. 2		600	300	65	425	425	1,000,000	NLGA
Select Structural	Posts and	1050	700	65	425	800	1,300,000	
No. 1	Timbers	850	550	65	425	700	1,300,000	
No. 2		500	325	65	425	500	1,000,000	
SPRUCE-PINE-FIR (SOUTH)								
Select Structural		1300	575	70	335	1200	1,300,000	
No. 1	2"-4" thick	850	400	70	335	1050	1,200,000	
No. 2	2" & wider	750	325	70	335	975	1,100,000	NELMA
Select Structural	Beams and	1050	625	65	335	675	1,200,000	
No. 1	Stringers	900	450	65	335	575	1,200,000	WCLIB
No. 2		575	300	65	335	350	1,000,000	NSLB
Select Structural	Posts and	1000	675	65	335	700	1,200,000	WWPA
No. 1	Timbers	800	550	65	335	625	1,200,000	
No. 2		350	225	65	335	225	1,000,000	
YELLOW POPLAR								
Select Structural		1000	575	75	420	900	1,500,000	
No. 1	2"-4" thick	725	425	75	420	725	1,400,000	NLSB
No. 2	2" & wider	700	400	75	420	575	1,300,000	

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers (Continued)

1. Design values are taken from the 1991 Edition of the NDS® and are for a 10-year load duration and dry service conditions. Refer to the 1991 NDS® for additional species and grades and for a summary of grading rules agencies and commercial species classifications.
2. Wet Services Factor, C_M. When dimension lumber, 2" to 4" thick is used where moisture content will exceed 19%, design values shall be multiplied by the following wet service factors:

WET SERVICE FACTORS, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E
0.85*	1.0	0.97	0.67	0.8**	0.9

* when $(F_b)(C_F) \leq$ 1,150 psi, C_M = 1.0
** when F_c 750 psi, C_M = 1.0

When timbers 5" by 5" and larger are used where moisture content will exceed 19%, design values shall be multiplied by the following wet service factors (for Southern Pine and Mixed Southern Pine, use tabulated values without further adjustment):

WET SERVICE FACTORS, C_M

F_b	F_t	F_v	F_c	F_c	E
1.00	1.00	1.00	0.67	0.91	1.00

3. Size Factor, C_F. For all species other than Southern Pine and Mixed Southern Pine, tabulated bending, tension, and compression parallel to grain design values for dimension lumber 2" to 4" thick shall be multiplied by the following size factors:

SIZE FACTORS, C_F

		F_b		F_t	F_c
		Thickness			
Grades	Width	2" & 3"	4"		
	2", 3" & 4"	1.5	1.5	1.5	1.15
Select	5"	1.4	1.4	1.4	1.1
Structural,	6"	1.3	1.3	1.3	1.1
No. 1 & Btr.	8"	1.2	1.3	1.2	1.05
No. 1, No. 2,	10"	1.1	1.2	1.1	1.0
No. 3	12"	1.0	1.1	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9

TABLE 13.5.1A Tabulated Design Values for Visually Graded Lumber and Timbers (Continued)

For Southern Pine and Mixed Southern Pine dimension lumber, 2" to 4" thick, appropriate size adjustment factors have been incorporated in tabulated values, with the following exceptions:

For dimension lumber 4" thick, 8" and wider, tabulated bending design values shall be multiplied by the size factor, $C_F = 1.1$.

For dimension lumber wider than 12", tabulated bending, tension, and compression parallel to grain design values for 12" wide lumber shall be multiplied by the size factor, $C_F = 0.9$.

4. Flat Use Factor, C_{fu}. Bending design values are based on edgewise use (load applied to narrow face). When dimension lumber 2" to 4" thick is used flatwise (load applied to wide face), the bending design value shall be multiplied by the following flat use factors:

FLAT USE FACTORS, C_{fu}

	Thickness	
Width	2" & 3"	4"
2" & 3"	1.0	...
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

5. Repetitive Member Factor, C_r. Bending design values for dimension lumber 2" to 4" thick shall be multiplied by the repetitive member factor $C_r = 1.15$, when such members are used as stringers, decking or similar members which are in contact or are spaced not more than 24" on centers, are not less than 3 in number and are joined by load distributing elements adequate to support the design load.

6. Shear Stress Factor, C_H. Tabulated shear design values parallel to grain, F_V, have been reduced to allow for the occurrence of splits, checks, and shakes and may be multiplied by the shear stress factors given below when the length of split, or size of check or shake is known and no increase in them is anticipated. When the shear stress factor is applied to Southern Pine or Mixed Southern Pine, a tabulated design value of $F_V = 90$ lb/in^2 shall be used for all grades. Shear stress factors shall be linearly interpolated.

SHEAR STRESS FACTORS, C_H

Length of split on wide face of 2" (nominal) lumber	C_H	Length of split on wide face of 3" (nominal) and thicker lumber	C_H	Size of shake* in 2" (nominal) and thicker lumber	C_H
no split	2.00	no split	2.00	no shake	2.00
$^1/_2$ × wide face	1.67	$^1/_2$ narrow face	1.67	$^1/_6$ narrow face	1.67
$^3/_4$ wide face	1.50	$^3/_4$ narrow face	1.50	$^1/_4$ narrow face	1.50
1 wide face	1.33	1 narrow face	1.33	$^1/_3$ narrow face	1.33
1-$^1/_2$ wide face or more	1.00	1-$^1/_2$ narrow face or more	1.00	$^1/_2$ narrow face or more	1.00

* Shake is measured at the end between lines enclosing the shake and perpendicular to the loaded face.

Table 13.5.1B Tabulated Design Values for Mechanically Graded Dimension Lumber

Species and Commercial Grade	Size Classification	Design Values in Pounds per Square Inch (psi): Bending F_b	Tension Parallel to Grain F_t	Compression Parallel to Grain F_c	Modulus of Elasticity E	Grading Rules Agency
MACHINE STRESS RATED (MSR) LUMBER						
900f-1.0E		900	350	1050	1,000,000	WCLIB, WWPA
1200f-1.2E		1200	600	1400	1,200,000	NLGA, SPIB, WCLIB, WWPA
1350f-1.3E		1350	750	1600	1,300,000	SPIB, WCLIB, WWPA
1450f-1.3E		1450	800	1625	1,300,000	NLGA, WCLIB, WWPA
1500f-1.3E		1500	900	1650	1,300,000	SPIB
1500f-1.4E		1500	900	1650	1,400,000	NLGA, SPIB, WCLIB, WWPA
1650f-1.4E		1650	1020	1700	1,400,000	SPIB
1650f-1.5E		1650	1020	1700	1,500,000	NLGA, SPIB, WCLIB, WWPA
1800f-1.6E		1800	1175	1750	1,600,000	NLGA, SPIB, WCLIB, WWPA
1950f-1.5E	2" & less in thickness	1950	1375	1800	1,500,000	SPIB
1950f-1.7E		1950	1375	1800	1,700,000	NLGA, SPIB, WWPA
2100f-1.8E	2" & wider	2100	1575	1875	1,800,000	NLGA, SPIB, WCLIB, WWPA
2250f-1.6E		2250	1750	1925	1,600,000	SPIB
2250f-1.9E		2250	1750	1925	1,900,000	NLGA, SPIB, WWPA
2400f-1.7E		2400	1925	1975	1,700,000	SPIB
2400f-2.0E		2400	1925	1975	2,000,000	NLGA, SPIB, WCLIB, WWPA
2550f-2.1E		2550	2060	2025	2,100,000	NLGA, SPIB, WWPA
2700f-2.2E		2700	2150	2100	2,200,000	NLGA, SPIB, WCLIB, WWPA
2850f-2.3E		2850	2300	2150	2,300,000	SPIB, WWPA
3000f-2.4E		3000	2400	2200	2,400,000	NLGA, SPIB
3150f-2.5E		3150	2500	2250	2,500,000	SPIB
3300f-2.6E		3300	2650	2325	2,600,000	SPIB
900f-1.2E		900	350	1050	1,200,000	NLGA, WCLIB
1200f-1.5E	2" & less in thickness	1200	600	1400	1,500,000	NLGA, WCLIB
1350f-1.8E		1350	750	1600	1,800,000	NLGA
1500f-1.8E	6" & wider	1500	900	1650	1,800,000	WCLIB
1800f-2.1E		1800	1175	1750	2,100,000	NLGA, WCLIB

1. Design Values are taken from the 1991 Edition of the NDS® and are for a 10-year load duration and dry service conditions. Refer to the 1991 NDS® for additional grades and for a summary of grading rules agencies.
2. Design values for shear parallel to grain and compression perpendicular to grain shall be as specified in Table 13.5.1A for No. 2 visually graded dimension lumber of the appropriate species.
3. Use of the wet service factor, shear stress factor, repetitive member factor, and flat use factor shall be as specified in Table 13.5.1A for visually graded dimension lumber.

\+ Edition of the American Institute of Timber Construction, AITC 117-93 Design, "Standard Specifications for structural Glued Laminated Timber of Softwood Species." Refer to AITC 117-93 Design for a more complete listing.

13.5.3.2 Tabulated values for hardwood species shall be as given in the 1985 Edition of American Institute of Timber Construction, AITC 119, "Standard Specifications for Hardwood Glued Laminated Timber."

13.5.3.3 Species other than those specifically included or referenced in this Section may be used, provided that tabulated values are established for each species in accordance with AASHTO M 168.

Table 13.5.2A Tabulated Design Values for Bearing Parallel to Grain

Species Combination	Wet Service Conditions	Dry Service Conditions: Sawn Lumber 5" x 5" & Larger	Dry Service Conditions: Sawn Lumber 2" to 4" Thick	Dry Service Conditions: Glued Laminated Timber
Douglas Fir-Larch (Dense)	1570	1730	2360	2750
Douglas Fir-Larch	1350	1480	2020	2360
Eastern Softwoods	880	--	1340	--
Hem-Fir	1110	1220	1670	1940
Mixed Southern Pine	1270	1390	1900	--
Northern Red Oak	1150	1270	1730	2010
Red Maple	1100	1210	1650	1930
Red Oak	1010	1110	1520	1770
Southern Pine	1320	1450	1970	2300
Southern Pine (Dense)	1540	1690	2310	2690
Spruce-Pine-Fir	940	1040	1410	1650
Spruce-Pine-Fir (South)	810	900	1220	1430
Yellow Poplar	890	--	1340	1560

1. Design Values are taken from the 1991 Edition of the NDS®. Refer to the 1991 NDS® for additional species.
2. Wet and dry service conditions are as defined in Article 13.5.5.1. The wet service factor has been applied to values tabulated for wet service conditions and further adjustment by this factor is not required.

13.5.4 Tabulated Values for Structural Composite Lumber

13.5.4.1 Representative tabulated design values for structural composite lumber are given in Table 13.5.4A for laminated veneer lumber and Table 13.5.4B for parallel strand lumber.

13.5.5 Adjustments to Tabulated Design Values

13.5.5.1 Wet Service Factor, C_M

13.5.5.1.1 Tabulated values for sawn lumber assume that the material is installed and used under continuously dry conditions where the moisture content of the wood does not exceed 19 percent. When the moisture content at installation or in service is expected to exceed 19 percent, tabulated values shall be reduced by the wet service factors, C_M, given in footnotes to Tables 13.5.1A and 13.5.1B.

13.5.5.1.2 Tabulated values for glued laminated timber and structural composite lumber assume that the material is used under continuously dry conditions where the moisture content in service does not exceed 16 percent. When the moisture content in service is expected to exceed 16 percent, tabulated values shall be reduced by the wet service factors, C_M, given in the footnotes to Tables 13.5.3A and 13.5.3B for glued laminated timber and Tables 13.5.4A and 13.5.4B for structural composite lumber.

13.5.5.1.3 The moisture content of wood used in exposed bridge applications will normally exceed 19 percent and tabulated values shall be reduced by the wet service factor unless an analysis of regional, geographical, and climatological conditions that affect moisture content indicate that the in-service moisture content will not exceed 19 percent for sawn lumber and 16 percent for glued laminated timber and structural composite lumber over the life of the structure.

13.5.5.2 Load Duration Factor, C_D

13.5.5.2.1 Wood can sustain substantially greater maximum loads for short load durations than for long load durations. Tabulated stresses for sawn lumber, glued laminated timber, and structural composite lumber are based on a normal load duration which contemplates that

TABLE 13.5.3A Design Values for Structural Glued Laminated Softwood Timber with Members Stressed Primarily in Bending[1,2,3,4,12]

		Design Values in Pounds per Square Inch (psi)													
		Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)						Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations)					Axially Loaded		
		Bending		Compression Perpendicular to Grain		(X-X area)			(Y-Y area)						
Combination Symbol[4]	Species Outer Laminations/ Core Laminations[5]	Tension Zone Stressed in Tension F_{bx}	Compression Zone Stressed in Tension[6] F_{bx}	Tension Face[9,10] $F_{c\perp x}$[10]	Compression Face[9,10] $F_{c\perp x}$	Shear Parallel to Grain[10] F_{vx}	Modulus of Elasticity E_x	Bending F_{by}	Compression Perpendicular to Grain (Side Faces) $F_{c\ y}$	Shear Parallel to Grain F_{vy}	Shear Parallel to Grain (For Members with Multiple Piece Laminations Which are Not Edge Glued)[13] F_{vy}	Modulus of Elasticity E_y	Tension Parallel to Grain F_t	Compression Parallel to Grain F_c	Modulus of Elasticity E
VISUALLY GRADED WESTERN SPECIES															
20F-V2	HF/HF	2000	1000	500[10]	375[10]	155	1,500,000	1200	375	135	70	1,400,000	950	1350	1,400,000
20F-V3	DF/DF	2000	1000	650	560[10]	165	1,600,000	1450	560	145	75	1,500,000	1000	1550	1,500,000
20F-V7[8]	DF/DF	2000	2000	650	650	165	1,600,000	1450	560	145	75	1,600,000	1000	1600	1,600,000
20F-V9[8]	HF/HF	2000	2000	500[10]	500[10]	155	1,500,000	1400	375	135	70	1,400,000	975	1400	1,400,000
24F-V4	DF/DF	2400	1200	650	650	165	1,800,000	1500	560	145	75	1,600,000	1150	1650	1,600,000
24F-V5	DF/HF	2400	1200	650	650	155	1,700,000	1350	375	140	70	1,500,000	1100	1450	1,500,000
24F-V[8]	DF/DF	2400	2400	650	650	165	1,800,000	1450	560	145	75	1,600,000	1100	1650	1,600,000
24F-V10[8]	DF/HF	2400	2400	650	650	156	1,800,000	1400	375	140	70	1,600,000	1150	1600	1,600,000
E-RATED WESTERN SPECIES															
24F-E5	DF/DF	2400	1200	650	650[10]	165	1,800,000	1650	560	145	75	1,600,000	1100	1550	1,600,000
24F-E13	DF/DF	2400	2400	650	650	165	1,800,000	1950	560	145	70	1,700,000	1250	1700	1,700,000
VISUALLY GRADED SOUTHERN PINE															
20F-V2	SP/SP	2000	1000	650	560[10]	200	1,600,000	1450	560	175	90	1,400,000	1050	1550	1,400,000
20F-V9[8]	SP/SP	2000	2000	650	650	200	1,600,000	1450	560	175	90	1,400,000	1050	1550	1,400,000
24F-V3	SP/SP	2400	1200	650	650	200	1,800,000	1600	560	175	90	1,600,000	1150	1700	1,600,000
24F-V5[8]	SP/SP	2400	2400	650	650	200	1,700,000	1600	560	175	90	1,500,000	1150	1700	1,500,000
20F-V1	SP/SP	2800	1300	650	650	200	1,800,000	1050	560	175	90	1,500,000	1150	1600	1,500,000
20F-V2	SP/SP	2800	1300	650	650	200	1,900,000	1050	650	175	90	1,700,000	1200	1650	1,700,000
20F-V3	SP/SP	2800	1300	650	650	200	1,900,000	1050	560	175	90	1,800,000	1150	1600	1,800,000
20F-V4	SP/SP	2800	2800	650	650	200	1,900,000	1050	560	175	90	1,700,000	1150	1600	1,700,000
E-RATED SOUTHERN PINE															
24F-E2	SP/SP	2400	1200	650	650	200	1,900,000	1700	560	175	90	1,600,000	1150	1700	1,600,000
24F-E4[8]	SP/SP	2400	2400	650	650	200	1,800,000	2000	560	175	90	1,600,000	1250	1750	1,600,000

TABLE 13.5.3A Design Values for Structural Glued Laminated Softwood Timber with Members Stressed Primarily in Bending (Continued)

1. Design values in this table are for a 10-year load duration and dry service conditions and are based on combinations conforming to AITC 117-93 (Design Standard Specifications for Structural Glued Laminated Timber of Softwood Species), by American Institute of Timber Construction, and manufactured in accordance with American National Standard ANSI/AITC A190.1-1991 (Structural Glued Laminated Timber). Refer to AITC 117-93 for additional combinations and design values.
2. The combinations in this table are intended primarily for members stressed in bending due to loads applied perpendicular to the wide faces of the laminations (bending about X-X axis). Design values are tabulated, however, for loading both perpendicular and parallel to the wide faces of the laminations, and for axial loading. For combinations applicable to members loaded primarily axial or parallel to the wide faces of the laminations, see Table 13.5.3B.
3. Design values in this table are applicable to members having 4 or more laminations. For members having 2 or 3 laminations, see Table 13.5.3B.
4. The 24F combinations for members 15" and less in depth may not be readily available and the designer should check availability prior to specifying. The 20F combinations are generally available for members 15" and less in depth.
5. The symbols used for species are Douglas Fir-Larch (DF), Hem-Fir (HF), and Southern Pine (SP). N3 refers to No.3 structural joists and planks or structural light framing grade.
6. Design values in this column are for bending when the member is loaded such that the compression zone laminations are subjected to tensile stresses. For more information, see AITC 117-93. The values in this column may be increased 200 psi where end-joint spacing restrictions are applied to the compression zone when stressed in tension.
7. These combinations are intended for straight or slightly cambered members for dry use and industrial appearance grade, because they may contain wane. If wane is omitted these restrictions do not apply.
8. These combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.
9. For bending members greater than 15" in depth, these design values for compression perpendicular to grain are 650 psi on the tension face.
10. These design values may be increased in accordance with AITC 117-93 when the member conforms with special construction requirements therein. For more information, see AITC 117-93.

TABLE 13.5.3A Design Values for Structural Glued Laminated Softwood Timber with Members Stressed Primarily in Bending (Continued)

11. For these combinations manufacturers may substitute E-rated Douglas Fir-Larch laminations that are 200,000 psi higher in modulus of elasticity than the specified E-rated Hem-Fir, with no change in design values.
12. Species groups for split ring and shear plate connectors should be determined by associated compression design values perpendicular to grain, $F_{c\perp}$, as follows:

$F_{c\perp}$ (psi)	Species Groups for Split Ring and Shear Plate Connectors
650*	A
590 or 560	B
500	C
470 or 375	C
315	C
255	D

* For $F_{c\perp}$ = 650 psi for Douglas Fir-South, use Group B.

13. The values for shear parallel to grain, F_{vx} and F_{vy}, apply to members manufactured using multiple piece laminations with unbonded edge joints. For members manufactured using single-piece laminations or using multiple-piece laminations with bonded-edge joints, the shear parallel to grain values in the previous column apply.
14. Wet Service Factor, C_M. When glued laminated timber is used where moisture content will exceed 16%, design values shall be multiplied by the appropriate wet service factors from the following table:

WET SERVICE FACTORS, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E
0.8	0.8	0.875	0.53	0.73	0.833

TABLE 13.5.3B Design Values for Structural Glued Laminated Softwood Timber with Members Stressed Primarily in Axial Tension or Compression[1,2 8,10]

All Loading				Design Values in Pounds per Square Inch (psi)												
				Axially Loaded			Bending About Y-Y Axis Loaded Parallel to Wide Faces of Laminations							Bending About X-X Axis Loaded Perpendicular to Wide Faces of Laminations		
				Tension Parallel to Grain	Compression Parallel to Grain		Bending			Shear Parallel to Grain[4]				Bending		Shear Parallel to Grain[4]
Combi-nation Symbol	Species[3]	Modulus of Elasticity E	Com-pression Perpen-dicular to Grain $F_{c\perp}$	2 or More Lami-nations F_t	4 or More Lami-nations F_c	2 or 3 Lami-nations F_c	4 or More Lami-nations F_{by}	3 Lami-nations F_{by}	2 Lami-nations F_{by}	4 or More Lami-nations (for Members with Multiple Piece Lami-nations)[9] F_{vy}	4 or More Lami-nations F_{vy}	3 Lami-nations F_{vy}	2 Lami-nations F_{vy}	2 Lami-nations to 15" deep[5] F_{bx}	4 or More Lami-nations[6] F_{bx}	2 or More Lami-nations F_{vx}
VISUALLY GRADED WESTERN SPECIES																
2	DF	1,700,000	560[7]	1250	1900	1600	1800	1600	1300	75	145	135	125	1700	2000	165
3	DF	1,800,000	650	1450	2300	1850	2100	1850	1550	75	145	135	125	2000	2300	165
5	DF	2,000,000	650	1600	2400	2100	2400	2100	1800	75	145	135	125	2200	2400	165
15	HF	1,400,000	375[7]	1050	1350	1300	1500	1350	1100	70	135	130	115	1450	1700	155
16	HF	1,600,000	375[7]	1200	1500	1450	1750	1550	1300	70	135	130	115	1600	1900	155
17	HF	1,700,000	500	1400	1750	1700	2000	1850	1550	70	135	130	115	1900	2200	155
VISUALLY GRADED SOUTHERN PINE																
47	SP	1,400,000	560[7]	1200	1900	1150	1750	1550	1300	90	175	165	150	1400	1600	200
48	SP	1,700,000	650	1400	2200	1350	2000	1800	1500	90	175	165	150	1600	1900	200
49	SP	1,170,000	560[7]	1350	2100	1450	1950	1750	1500	90	175	165	150	1800	2100	200
50	SP	1,900,000	650	1550	2300	1700	2300	2100	1750	90	175	165	150	2100	2400	200

TABLE 13.5.3B Design Values for Structural Glued Laminated Softwood Timber with Members Stressed Primarily in Axial Tension or Compression (Continued)

1. Design values in this table are for a 10-year load duration and dry service conditions and are based on combinations conforming to AITC 117-93 (Design Standard Specifications for Structural Glued Laminated Timber of Softwood Species), by American Institute of Timber Construction, and manufactured in accordance with American National Standard ANSI/AITC A190.1-1991 (Structural Glued Laminated Timber). Refer to AITC 117-93 for additional combinations and design values.
2. The combinations in this table are intended primarily for members loaded either axially or in bending with the loads acting parallel to the wide faces of the laminations (bending about Y-Y axis). Design values for bending due to loads applied perpendicular to the wide faces of the laminations (bending about X-X axis) are also included, although the combinations in Table 13.5.3A are usually better suited for this condition of loading.
3. The symbols used for species are Douglas Fir-Larch (DF), Hem-Fir (HF), and Southern Pine (SP).
4. The design values in shear parallel to grain are based on members that do contain wane.
5. The design values in bending about the X-X axis in this column are for members up to 15" in depth without tension laminations.
6. The design values in bending about the X-X axis in this column are for members having specific tension laminations and apply to members having 4 or more laminations. When these values are used in design and the member is specified by combination symbol, the design should also specify the required bending design value.
7. These design values may be increased in accordance with AITC 117-93 when member conforms with special construction requirements therein. For more information see AITC 117-93.
8. Species groups for split ring and shear plate connectors should be determined by associated compression design values perpendicular to grain, $F_{c\perp}$, as given in Table 13.5.3A.
9. The values for shear parallel to grain, F_{vyy}, apply to members manufactured using multiple-piece laminations with unbonded edge joints. For members using single-piece laminations or using multiple-piece laminations with bonded-edge joints the shear parallel to grain values tabulated in the next three columns apply.
10. Wet Service Factor, C_M. When glued laminated timber is used where moisture content will exceed 16%, design values shall be multiplied by the appropriate wet service factors given in the footnotes to Table 13.5.3A.

TABLE 13.5.4A Representative Tabulated Design Values for Laminated Veneer Lumber[1]

Species	Grade	Extreme Fiber in Bending F_b	Tension Parallel to Grain[2] F_t	Compression Parallel to Grain[2] F_c	Compression Perpendicular to Grain $F_{c\perp}$ — Load Direction: Parallel to glueline	Compression Perpendicular to Grain $F_{c\perp}$ — Load Direction: Perpendicular to glueline	Horizontal Shear F_v — Load Direction: Parallel to glueline	Horizontal Shear F_v — Load Direction: Perpendicular to glueline	Modulus of Elasticity E
		Design Values in Pounds Per Square Inch (psi)[3]							
Douglas-Fir	2.0E	2800	1750	2725	750	480	285	175	2,000,000
Southern Pine	2.0E	2925	1805	3035	880	525	285	150	2,000,000

1. Design values are representative of species and grades that are commonly available from manufacturers and are for a 10-year load duration and dry service conditions.

2. Tabulated values in tension parallel to grain shall be adjusted by the size factor, C_F, given by the following equation:

$$C_F = \left(\frac{3}{L}\right)^{1/m}$$

where:

L = length of tension member in feet;
m = parameter for the specific material determined in accordance with the requirements of ASTM D-5456.

3. Wet Service Factor, C_M. When laminated veneer lumber is used where moisture content will exceed 16%, design values shall be multiplied by the following wet service factors:

WET SERVICE FACTORS, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E
0.8	0.8	0.875	0.53	0.73	0.833

TABLE 13.5.4B Representative Tabulated Design Values for Parallel Strand Lumber[1] Design Values in Pounds Per Square Inch (psi)[3]

Species	Grade	Extreme Fiber in Bending F_b	Tension Parallel to Grain[2] F_t	Compression Parallel to Grain F_c	Compression Perpendicular to Grain $F_{c\perp}$, Load Direction: Parallel to wide face of strand	Compression Perpendicular to Grain $F_{c\perp}$, Load Direction: Perpendicular to wide face of strand	Horizontal Shear F_v, Load Direction: Parallel to wide face of strand	Horizontal Shear F_v, Load Direction: Perpendicular to wide face of strand	Modulus of Elasticity E
Douglas-Fir	2.0E	2900	2400	2900	750	480	290	210	2,000,000
Southern Pine	2.0E	2900	2400	2900	880	525	290	210	2,000,000

1. Design values are representative of species and grades that are commonly available from manufacturers and are for a 10-year load duration and dry service conditions.

2. Tabulated values in tension parallel to grain shall be adjusted by the size factor, C_F, given by the following equation:

$$C_F = \left(\frac{3}{L}\right)^{1/m}$$

where:

L = length of tension member in feet:
m = parameter for the specific material determined in accordance with the requirements of ASTM D-5456.

3. Wet Service Factor, C_M. When parallel strand lumber is used where moisture content will exceed 16%, design values shall be multiplied by the following wet service factors:

WET SERVICE FACTORS, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E
0.8	0.8	0.875	0.53	0.73	0.833

the member is stressed to the maximum stress level, either continuously or cumulatively, for a period of approximately 10 years, and/or stressed to 90 percent of the maximum design level continuously for the remainder of the member life.

13.5.5.2.2 When the full maximum load is applied either cumulatively or continuously for periods other than 10 years, tabulated stresses shall be multiplied by the load duration factor, C_D, given in Table 13.5.5A.

13.5.5.2.3 The provisions of this article do not apply to modulus of elasticity or to compression perpendicular to grain, but do apply to mechanical fastenings, except as otherwise noted. The load duration factor for impact does not apply to members pressure-impregnated with preservative salts to the heavy retentions required for marine exposure.

13.5.5.2.4 Increases in tabulated stresses resulting from various load duration factors are not cumulative and the load duration factor for the shortest duration load in a combination of loads shall apply for that load combination. The resulting structural members shall not be smaller than required for a longer duration of loading (refer to the 1991 Edition of the NDS ® for additional commentary).

13.5.5.2.5 Modification of design stresses for load combinations, as specified in Section 3, are cumulative with load duration adjustments.

13.5.5.3 Adjustment for Preservative Treatment

Tabulated values apply to untreated wood and to wood that is preservatively treated in accordance with the requirements of AASHTO M 133, Unless otherwise noted, no adjustment of tabulated values is required for preservative treatment.

TABLE 13.5.5A Load Duration Factor, C_D

Load Duration	C_D
Permanent	0.90
2 months (vehicle live load)	1.15
7 days	1.25
1 day	1.33
5 minutes (railing only)	1.65

13.6 BENDING MEMBERS

13.6.1 General

13.6.1.1 The provisions of this article are applicable to straight members and to slightly curved bending members where the radius of curvature exceeds the span in inches divided by 800. Additional design requirements for curved glued laminated timber members shall be as specified in the 1991 Edition of the NDS®.

13.6.1.2 For simple, continuous, and cantilevered bending members, the span shall be taken as the clear distance between supports plus one-half the required bearing length at each support.

13.6.1.3 Bending members shall be transversely braced to prevent lateral displacement and rotation and transmit lateral forces to the bearings. Transverse bracing shall be provided at the supports for all span lengths and at intermediate locations as required for lateral stability and load transfer (Article 13.6.4.4). The depth of transverse bracing shall not be less than ¾ the depth of the bending member.

13.6.1.4 Support attachments for bending members shall be of sufficient size and strength to transmit vertical, longitudinal and transverse loads from the superstructure to the substructure in accordance with the requirements of Section 3.

13.6.1.5 Glued laminated timber and structural +
composite lumber girders shall preferably be cambered a +
minimum 3 times the computed dead load deflection, but +
not less than 2 times dead load deflection or 1600 ft – +
2000 ft radius. See AITC Timber Construction Manual +
1994 Edition 4.3 "Camber" and Table 4.5. +

13.6.2 Notching

Notching of bending members can severely reduce member capacity and is not recommended. When notching is required for sawn lumber members, design limitations and requirements shall be in accordance with the NDS®, 1991 Edition. Design requirements and limitations for notching glued laminated timber members shall be as given in the "Timber Construction Manual," 1994 4th Edition by the American Institute of Timber Construction, published by John Wiley & Sons, New York, New York. Design requirements and limitations for notching structural composite lumber shall be as specified for glued laminated timber.

13.6.3 Modulus of Elasticity

The modulus of elasticity used for stiffness and stability computations shall be the tabulated modulus of elasticity adjusted by the applicable adjustment factor given in the following equation:

$$E' = EC_M \qquad (13\text{-}1)$$

where:

E' = allowable modulus of elasticity in psi;
E = tabulated modulus of elasticity in psi;
C_M = wet service factor from Article 13.5.5.1.

13.6.4 Bending

13.6.4.1 Allowable Stress

The allowable unit stress in bending shall be the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F'_b = F_b C_M C_D C_F C_V C_L C_f C_{fu} C_r \qquad (13\text{-}2)$$

where:

F'_b = allowable unit stress in bending psi
F_b = tabulated unit stress in bending psi
C_M = wet service factor from Article 13.5.5.1
C_D = load duration factor from Article 13.5.5.2
C_F = bending size factor for sawn lumber and structural composite lumber, and for glued laminated timber with loads applied parallel to the wide face of the laminations, from Article 13.6.4.2
C_V = volume factor for glued laminated timber with loads applied perpendicular to the wide face of the laminations, from Article 13.6.4.3
C_L = beam stability factor from Article 13.6.4.4.
C_f = form factor from Article 13.6.4.5
C_{fu} = flat use factor for sawn lumber from footnotes to Tables 13.5.1A and 13.5.1B
C_r = repetitive member factor for sawn lumber from footnotes to Table 13.5.1A

The volume factor, C_V, shall not be applied simultaneously with the beam stability factor, C_L, and the lesser of the two factors shall apply in Equation 13-2.

13.6.4.2 Size Factor, C_F

13.6.4.2.1 The tabulated bending stress, for dimension lumber 2 inches to 4 inches thick shall be multiplied by the bending size factor, C_F, given in the footnotes to Table 13.5.1A.

13.6.4.2.2 For rectangular sawn lumber bending members 5 inches or thicker and greater than 12 inches in depth, and for glued laminated timber with loads applied parallel to the wide face of the laminations and greater than 12 inches in depth, the tabulated bending stress shall be multiplied by the size factor, C_F, determined from the following relationship:

(13-3)

where d is the member depth in inches.

13.6.4.2.3 For structural composite lumber bending members of any width, the tabulated bending stress shall be reduced by the size factor, C_F , given by the following equation:

$$C_F = (21/L)^{1/m}(12/d)^{1/m} \qquad (13\text{-}4)$$

where:

L = length of bending member between points of zero moment in feet;
d = depth of bending member in inches;
m = parameter for the specific material determined in accordance with the requirements of ASTM D 5456.

13.6.4.3 Volume Factor, C_V

13.6.4.3.1 The tabulated bending stress for glued laminated timber bending members with loads applied perpendicular to the wide face of the laminations shall be adjusted by the volume factor, C_V, as determined by the following relationship.

$$C_v - (21/L)^{1/x}(12/d)^{1/x}(5.125/b)^{1/x} \leq 1.0 \qquad (13\text{-}5)$$

where:

- L = length of bending member between points of zero moment in feet;
- d = depth of bending member in inches;
- b = width of bending member in inches;
- x = 20 for Southern Pine
- x = 10 for all other species

13.6.4.3.2 When multiple piece width layups are used, the width of the bending member used in Equation 13-4 shall be the width of the widest piece used in the layup.

13.6.4.4 Beam Stability Factor, C_L

13.6.4.4.1 Tabulated bending values are applicable to members which are adequately braced. When members are not adequately braced, the tabulated bending stress shall be modified by the beam stability factor, C_L.

13.6.4.4.2 When the depth of a bending member does not exceed its width, or when lateral movement of the compression zone is prevented by continuous support and points of bearing have lateral support to prevent rotation, there is no danger of lateral buckling and C_L = 1.0. For other conditions, the beam stability factor shall be determined in accordance with the following provisions.

13.6.4.4.3 The bending member effective length, l_e, shall be determined from the following relationships for any loading condition:

$l_e = 2.06 l_u$	when $l_u/d < 7$	
$l_e = 1.63 l_u + 3d$	when $7 \leq l_u/d$	14.3
$l_e = 1.84 l_u$	when $l_u/d > 14.3$	

where:

- l_e = effective length in inches;
- l_u = unsupported length in inches;
- d = depth of bending member in inches.

If lateral support is provided to prevent rotation at the points of bearing, but no other lateral support is provided throughout the bending member length, the unsupported length, l_u, is the distance between points of bearing, or the length of a cantilever.

If lateral support is provided to prevent rotation and lateral displacement at intermediate points as well as at the bearings, the unsupported length, l_u, is the distance between such points of intermediate lateral support.

13.6.4.4.4 The slenderness ratio for bending members, R_B, is determined from the following equation:

≤

$$R_B = \sqrt{\frac{l_e d}{b^2}} \leq 50 \qquad (13\text{-}6)$$

where:

- R_B = bending member slenderness ratio;
- d = depth of bending member in inches;
- b = width of bending member in inches.

13.6.4.4.5 The beam stability factor, C_L, shall be computed as follows:

$$C_L = \frac{1 + \left(F_{bE}/F_b^*\right)}{1.90} - \sqrt{\frac{\left(1 + F_{bE}/F_b^*\right)^2}{3.61} - \frac{F_{bE}/F_b^*}{0.95}} \qquad (13\text{-}7)$$

$$F_{bE} = \frac{K_{bE} E'}{R_B^2} \qquad (13\text{-}8)$$

where:

- F_b^* = tabulated bending stress adjusted by all applicable adjustment factors given in Equation 13-2 except the volume factor, C_v, the beam stability factor, C_L, and the flat-use factor, C_{fu};
- K_{bE} = 0.438 for visually graded sawn lumber 0.609 for glued laminated timber, structural composite lumber, and machine stress rated lumber;
- E' = allowable modulus of elasticity in psi as determined by Article 13.6.3.

13.6.4.5 Form Factor, C_f

For bending members with circular cross sections the tabulated bending stress shall be adjusted by the form factor, C_f = 1.18. A tapered circular section shall be considered as a bending member of variable cross section.

13.6.5 Shear Parallel to Grain

13.6.5.1 General

13.6.5.1.1 The provisions of this article apply to shear parallel to grain (horizontal shear) at or near the points of vertical support of solid bending members. Refer to the 1991 edition of the NDS® for additional design requirements for other member types.

13.6.5.1.2 The critical shear in wood bending members is shear parallel to grain. It is unnecessary to verify the strength of bending members in shear perpendicular to grain.

13.6.5.2 Actual Stress

The actual unit stress in shear parallel to grain due to applied loading on rectangular members shall be determined by the following equation:

$$f_v = \frac{3V}{2bd} \qquad (13\text{-}9)$$

where:

f_v = actual unit stress in shear parallel to grain in psi;
b = width of bending member in inches;
d = depth of bending member in inches;
V = vertical shear in pounds, as determined in accordance with the following provisions.

For uniformly distributed loads, such as dead load, the magnitude of vertical shear used in Equation 13-9 shall be the maximum shear occurring at a distance from the support equal to the bending member depth, d. When members are supported by full bearing on one surface, with loads applied to the opposite surface, all loads within a distance from the supports equal to the bending member depth shall be neglected.

For vehicle live loads, the loads shall be placed to produce the maximum vertical shear at a distance from the support equal to three times the bending member depth, 3d, or at the span quarter point, L/4, whichever is the lesser distance from the support. The distributed live load shear used in Equation 13-9 shall be determined by the following expression:

$$V_{LL} = 0.50\left[\left(0.60\, V_{LU}\right) + V_{LD}\right] \qquad (13\text{-}10)$$

where:

V_{LL} = distributed live load vertical shear in pounds;
V_{LU} = maximum vertical shear, in pounds, at 3d or L/4 due to undistributed wheel loads;
V_{LD} = maximum vertical shear, in pounds, at 3d or L/4 due to wheel loads distributed laterally as specified for moment in Article 3.23.

For undistributed wheel loads, one line of wheels is assumed to be carried by one bending member.

13.6.5.3 Allowable Stress

The allowable unit stress in shear parallel to grain shall be the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F_v' = F_v C_M C_D \qquad (13\text{-}11)$$

where:

= allowable unit stress in shear parallel to grain in psi;
F_v = tabulated unit stress in shear parallel to grain in psi;
C_M = wet service factor from Article 13.5.5.1;
C_D = load duration factor from Article 13.5.5.2.

For sawn lumber beams, further adjustment by the shear stress factor may be applicable as described in the footnotes to Table 13.5.1A.

For structural composite lumber, more restrictive adjustments to the tabulated shear stress parallel to grain shall be as recommended by the material manufacturer.

13.6.6 Compression Perpendicular to Grain

13.6.6.1 General

When calculating the bearing stress in compression perpendicular to grain at beam end, a uniform stress distribution shall be assumed.

13.6.6.2 Allowable Stress

The allowable unit stress in compression perpendicular to grain shall be the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F_{c\perp}' = F_{c\perp} C_M C_b \qquad (13\text{-}12)$$

$\perp$	=	allowable unit stress in compression perpendicular to grain, in psi;
$\perp$	=	tabulated unit stress in compression perpendicular to grain, in psi;
C_M	=	wet service factor from Article 13.5.5.1;
C_b	=	bearing area factor from Article 13.6.6.3.

13.6.6.3 Bearing Area Factor, C_b

Tabulated values in compression perpendicular to grain apply to bearings of any length at beam ends, and to all bearings 6 inches or more in length at any other location. For bearings less than 6 inches in length and not nearer than 3 inches to the end of a member, the tabulated value shall be adjusted by the bearing area factor, C_b, given by the following equation:

$$C_b = \frac{l_b + 0.375}{l_b} \qquad (13\text{-}13)$$

where l_b is the length of bearing in inches, measured parallel to the wood grain. For round washers, or other round bearing areas, the length of bearing shall be the diameter of the bearing area.

The multiplying factors for bearing lengths on small areas such as plates and washers are given in Table 13.6.1A.

TABLE 13.6.1A Values of the Bearing Area Factor, Cb, for Small Bearing Areas

Length of Bearing, l_b (in.)	1/2	1	1-1/2	2	3	4	6 or more
Bearing Area Factor, C_b	1.75	1.38	1.25	1.19	1.13	1.10	1.00

13.6.7 Bearing on Inclined Surfaces

For bearing on an inclined surface, the allowable unit stress in bearing shall be as given by the following equation:

$$F_\theta' = \frac{F_g' F_{c\perp}'}{F_g' \sin^2\theta + F_{c\perp}' \cos^2\theta} \qquad (13\text{-}14)$$

where:

F_θ'	=	allowable unit stress for bearing on an inclined surface, in psi;
	=	allowable unit stress in bearing parallel to grain from Article 13.7.4;
$\perp$	=	allowable unit stress in compression perpendicular to the grain from Article 13.6.6;
	=	angle in degrees between the direction of load and the direction of grain.

13.7 COMPRESSION MEMBERS

13.7.1 General

13.7.1.1 The provisions of this article apply to simple solid columns consisting of a single piece of sawn lumber, piling, structural composite lumber, or glued laminated timber. Refer to the 1991 Edition of the NDS® for design requirements for built-up columns, consisting of a number of solid members joined together with mechanical fasteners, and for spaced columns consisting of two or more individual members with their longitudinal axes parallel, separated and fastened at the ends and at one or more interior points by blocking.

13.7.1.2 The term "column" refers to all types of compression members, including members forming part of a truss or other structural components.

13.7.1.3 Column bracing shall be provided where necessary to provide lateral stability and resist wind or other lateral forces.

13.7.2 Eccentric Loading or Combined Stresses

Members with eccentric loading or combined stresses shall be designed in accordance with the provisions of the NDS®, 1991 Edition.

13.7.3 Compression

13.7.3.1 Net Section

The actual unit stress in compression parallel to grain, f_c, shall be based on the net section as described in Article 13.1, except that it may be based on the gross section when the reduced section does not occur in the critical part of the column length that is most subject to potential buckling.

13.7.3.2 Allowable Stress

The allowable unit stress in compression parallel to grain shall not exceed the tabulated stress adjusted by the applicable adjustment factors given in the following equation:

$$F'_c = F_c C_M C_D C_F C_P \qquad (13\text{-}15)$$

where:

= allowable unit stress in compression parallel to grain in psi;
F_c = tabulated unit stress in compression parallel to grain in psi;
C_M = wet service factor from Article 13.5.5.1;
C_D = load duration factor from Article 13.5.5.2;
C_F = compression size factor for sawn lumber from footnotes to Table 13.5.1A;
C_P = column stability factor from Article 13.7.3.3.

13.7.3.3 Column Stability Factor, C_P

13.7.3.3.1 Tabulated values in compression parallel to grain are applicable to members which are adequately braced. When members are not adequately braced, the tabulated stress shall be modified by the column stability factor, C_P.

13.7.3.3.2 When a compression member is supported throughout its length to prevent lateral displacement in all directions, $C_P = 1.0$. For other conditions, the column stability factor shall be determined in accordance with the following provisions.

13.7.3.3.3 The effective column length, l_e, shall be determined in accordance with good engineering practice.

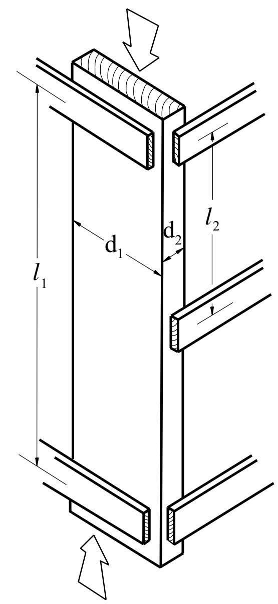
Actual column length l, may be multiplied by an effective length factor to determine the effective column length:

$$l_e = Kl \qquad (13\text{-}16)$$

where:

l_e = effective column length in inches
K = effective length factor from Table C-1 of Appendix C
l = actual column length between points of lateral support in inches.

13.7.3.3.4 For columns of rectangular cross section, the column slenderness ratio l_e/d, shall be taken as the larger of the ratios, l_{e1}/d_1 or l_{e2}/d_2. (See Figure 13.7.1A) The slenderness ratio shall not exceed 50.



l_1 and l_2 = distances between points of lateral support in planes 1 and 2, inches.
d_1 and d_2 = cross-sectional dimensions of rectangular compression member in planes of lateral support, inches.

FIGURE 13.7.1A

13.7.3.3.5 The column stability factor, C_P, shall be as given by the following expressions:

(13-17) +

$$F_{cE} = \frac{K_{cE} E'}{(l_e/d)^2} \qquad (13\text{-}18)$$

TABLE 13.7.1A Support Condition Coefficients for Tapered Columns

Support Condition	Support Condition Coefficient, a
Large end fixed, small end unsupported	0.70
Small end fixed, large end unsupported	0.30
Both ends simply supported	
Tapered toward one end	0.50
Tapered towards both ends	0.70

where:

F_c^* = tabulated stress in compression parallel to grain adjusted by all applicable modification factors given in Equation 13-14 except C_p;
K_{cE} = 0.300 for visually graded sawn lumber; 0.418 for glued laminated timber, structural composite lumber, and machine stress-rated lumber;
c = 0.80 for sawn lumber;
0.85 for round piles;
0.90 for glued laminated timber and structural composite lumber.

F'_g

For especially severe service conditions or extraordinary hazardous conditions, the use of lower design values than those obtained above may be necessary. Refer to the 1991 Edition of the NDS®.

13.7.3.4 Tapered Columns

13.7.3.4.1 For rectangular columns tapered at one or both ends, the cross-sectional area shall be based on the representative dimension of each tapered face. The representative dimension, d_{rep}, of each tapered face shall be based on the support condition coefficient given in Table 13.7.1A.

13.7.3.4.2 For support conditions given in Table 13.7.1A, the representative dimension, d_{rep}, of each tapered face shall be as given by the following equation:

$$d_{rep} = d_{min} + (d_{max} - d_{min})\left[a - 0.15\left(1 - \frac{d_{min}}{d_{max}}\right)\right] \qquad (13\text{-}19)$$

where:

d_{rep} = representative dimension for a tapered column face, in inches;
d_{min} = minimum column face dimension, in inches;
d_{max} = maximum column face dimension, in inches;
a = coefficient based on support conditions.

13.7.3.4.3 For support conditions other than those in Table 13.7.1A, the representative dimension of each tapered face shall be as given by the following equation:

$$d_{rep} = d_{min} + 0.33(d_{max} - d_{min}) \qquad (13\text{-}20)$$

13.7.3.4.4 For any tapered column, the actual stress in compression parallel to grain, f_c, shall not exceed the allowable stress determined by Equation 13-14, assuming the column stability factor C_p = 1.0.

13.7.3.5 Round Columns

The design of a round column shall be based on the design of a square column of the same cross-sectional area with the same degree of taper.

13.7.4 Bearing Parallel to Grain

13.7.4.1 The actual stress in bearing parallel to grain shall be based on the net area and shall not exceed the tabulated stress for bearing parallel to grain adjusted by the applicable adjustment factor given in the following equation:

$$F'_g = F_g C_D \qquad (13\text{-}21)$$

where:

= allowable unit stress in bearing parallel to grain in psi;
F_g = tabulated unit stress in bearing parallel to grain from Table 13.5.2A, in psi;
C_D = load duration factor from Article 13.5.5.2.

13.7.4.2 When the bearing load is at an angle to the grain, the allowable bearing stress shall be determined by Equation 13-14, using the design values for end-grain bearing parallel to grain and design values in compression perpendicular to grain.

13.7.4.3 When bearing parallel to grain exceeds 75% of the allowable value determined by Equation 13-21, bearing shall be on a metal plate or on other durable, rigid, homogeneous material of adequate strength and stiffness to distribute applied loads over the entire bearing area.

13.8 TENSION MEMBERS

13.8.1 Tension Parallel to Grain

The allowable unit stress in tension parallel to grain shall be the tabulated value adjusted by the applicable adjustment factors given in the following equation:

(13-22)

where:

= allowable unit stress in tension parallel to grain in psi;
= tabulated unit stress in tension parallel to grain in psi;
C_M = wet service factor from Article 13.5.5.1;
C_D = load duration factor from Article 13.5.5.2;
C_F = tension size factor for sawn lumber from footnotes to Table 13.5.1A and for structural composite lumber from footnotes to Tables 13.5.4A and 13.5.4B.

13.8.2 Tension Perpendicular to Grain

Designs which induce tension perpendicular to the grain of wood members should not be used. When tension perpendicular to grain cannot be avoided, mechanical reinforcement sufficient to resist all such forces should be used. Refer to the 1991 Edition of the NDS® for additional information.

13.9 MECHANICAL CONNECTIONS

13.9.1 General

13.9.1.1 Except as otherwise required by this specification, mechanical connections and their installation shall conform to the requirements of the NDS®, 1991 Edition.

13.9.1.2 Components at mechanical connections, including the wood members, connecting elements, and fasteners, shall be proportioned so that the design strength equals or exceeds the required strength for the loads acting on the structure. The strength of the connected wood components shall be evaluated considering the net section, eccentricity, shear, tension perpendicular to grain and other factors that may reduce component strength.

13.9.2 Corrosion Protection

13.9.2.1 Except as permitted by this section, all steel hardware for wood structures shall be galvanized in accordance with AASHTO M 232 or cadmium plated in accordance with AASHTO M 299.

13.9.2.2 All steel components, timber connectors, and castings, other than malleable iron, shall be galvanized in accordance with AASHTO M111.

13.9.2.3 Alternative corrosion protection coatings, such as epoxies, may be used when the demonstrated performance of the coating is sufficient to provide adequate protection for the intended exposure conduction.

13.9.2.4 Heat-treated alloy components and fastenings shall be protected by an approved alternative protective treatment that does not adversely affect the mechanical properties of the material.

13.9.3 Fasteners

13.9.3.1 Fastener design values shall be adjusted by the applicable adjustment factors for the intended use condition.

13.9.3.2 When determining fastener design values, wood shall be assumed to be used under wet-use or exposed to weather conditions.

13.9.3.3 Glulam rivets shall not be used in permanent structures.

13.9.4 Washers

13.9.4.1 Washers shall be provided under bolt and lag screw heads and under nuts that are in contact with wood. Washers may be omitted under heads of special timber bolts or dome-head bolts when the size and strength of the head is sufficient to develop connection strength without excessive wood crushing.

13.9.4.2 Washers shall be of sufficient size and strength to prevent excessive wood crushing when the fastener is tightened. For bolts or rods loaded in tension, washers shall be of sufficient size and strength to develop the tensile strength of the connection without excessive bending or exceeding wood strength in compression perpendicular to grain.